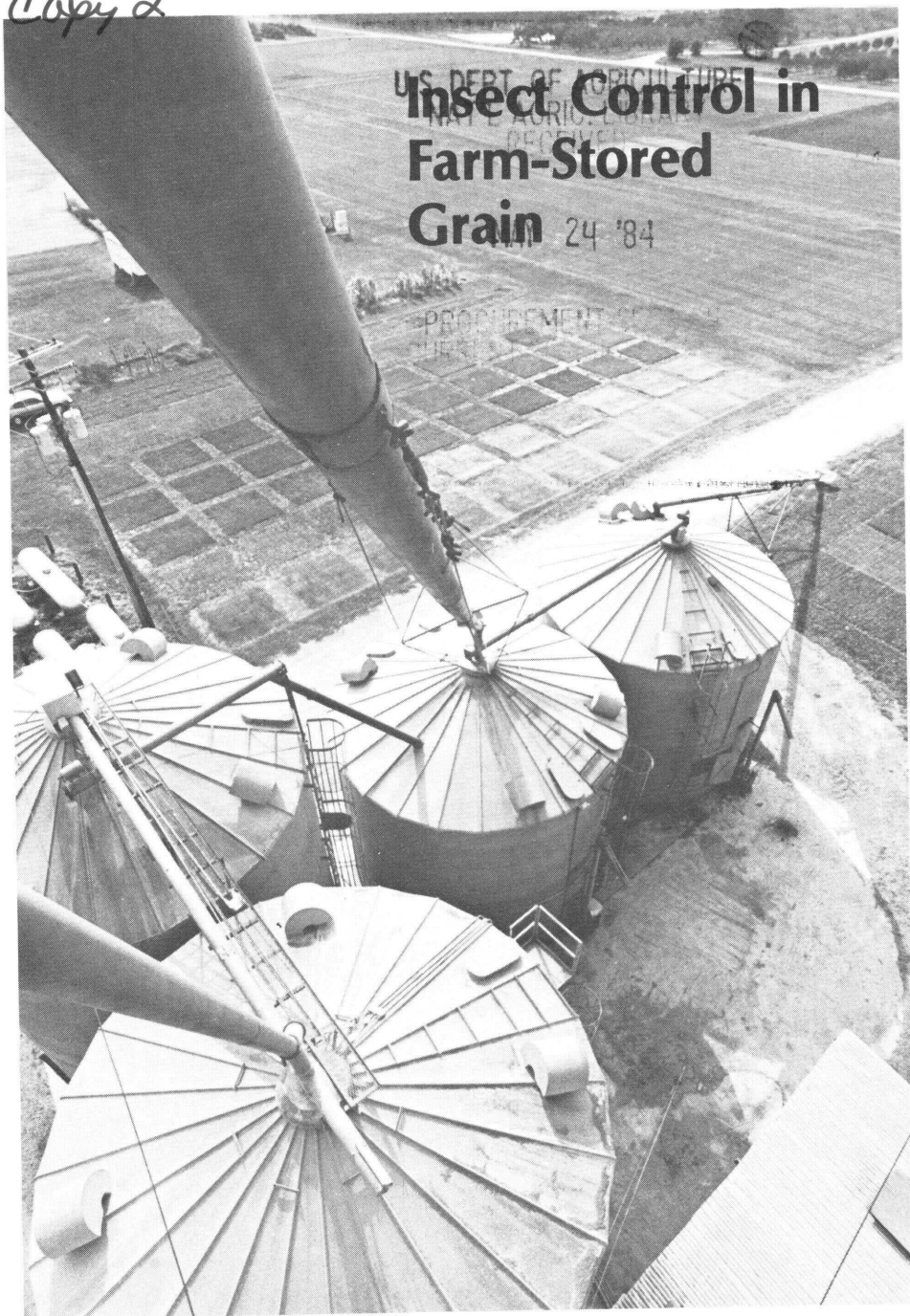


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Insect Control in Farm-Stored Grain



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Supersedes Leaflet No. 553,
"Controlling Insects in
Farm-Stored Grain"

Insect Control in Farm-Stored Grain

Charles L. Storey,
Roy D. Speirs, and
Lyman S. Henderson¹

How Insects Affect Quality and Market Value of Grain

When you store wheat, oats, rye, barley, grain sorghum, shelled corn, or other grains on your farm for extended periods, you must take steps to preserve its quality and prevent economic loss from insect damage.

Insects damage grain directly by feeding on the kernels and indirectly by contaminating the grain with their waste, cast skins, webbing, and body parts. They may also contribute to the conditions that cause grain to heat and mold. When infested grain is processed into human or animal food, insect fragments in the milled products could cause the Food and Drug Administration to reject the product.

Market value of infested grain may be substantially reduced if the number of insect-damaged kernels is sufficient to lower the grade of the grain (total damage factor), or if the number of insects in the grain causes it to be designated "weevily" on the grade certificate. Discounts against the price paid per bushel are often assessed by the buyer if live insects are present in the grain. And some grain dealers may refuse to accept heavily infested grain that might contami-

nate their storage facilities.

Insects in farm-stored grain will also affect its eligibility in the Grain Reserve Program. Condition of the storage structure and the commodity stored within the structure are factors that must be considered by the Agricultural Stabilization and Conservation Service commodity inspector when determining eligibility for a farm-storage loan. When a loan is approved, the producer is responsible for any loss in quantity or quality of the commodity caused by insect infestation or rodent damage.

Foreign sales of grain produced in the United States are important to the economy of the individual grain producer and to the trade balance of the nation. However, competition among grain-producing countries for export markets has substantially increased during recent years. Although price has been the major factor in determining the volume of grains that a nation could sell in world markets, grain quality has become increasingly important to successful marketing.

In the marketing system, insects or fungi in grain during storage and transport greatly affect its quality. Low levels of insect infestation in farm-stored grain can develop into damaging populations before the grain reaches its final destination.

Therefore, grain stored on the farm must be kept free of these pests to insure its acceptance by both domestic and foreign grain buyers.

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Factors That Influence Insect Infestations

Regional Climates

Many insects that attack stored grain were originally from the tropics. They spread and adapted to colder climates by living in manmade food storage shelters. Because stored-grain insects cannot remain active at low temperatures, their potential for development and damage is much greater in the southern regions of the United States (see fig. 1) where warm temperatures permit them to reproduce and develop the year round. Infestation often starts in warm regions while the grain is still in the field and then is carried into storages with the harvested grain.

Harvest Conditions

Harvesting grain too wet not only provides an environment for insects to develop but quickly leads to invasion and development of storage fungi. Fungal spores can then be distributed further throughout the grain storage by migrating insects. During harvest, mechanical damage to grain also can affect development. Some stored grain pests cannot survive in whole grain; others will survive on unbroken kernels. Their development, however, is aided if broken kernels and dockage are present. Crops should be harvested as dry as possible, and the com-

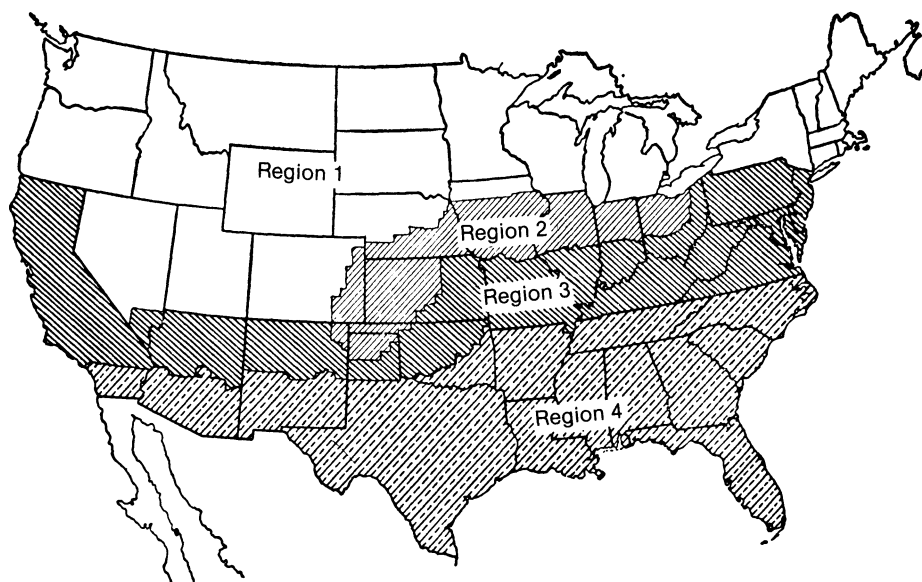


Figure 1—The map shows, by regions, the degree to which farm-stored grain in the United States is subject to insect attack: Region 1, little if any damage occurs to grain on the farm during the first season's

storage. Region 2, insects may be troublesome during the first season. Region 3, insects are troublesome every year. Region 4, insects are a serious problem throughout the storage period.

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bine should be adjusted properly to eliminate chaff and as many weeds and weed seeds as possible while still holding cracked or unbroken kernels to a minimum.

Small residues of grain in conveyers, trucks, and harvesters are particularly susceptible to stored-grain insects and storage fungi, and under certain temperatures and moisture conditions will provide the necessary habitat for large populations to develop. Therefore, inspecting, removing, and treating these small grain residues before harvest is advisable to prevent contaminating newly harvested grain.

Grain Temperature and Moisture

Most insect pests of stored grain have a short period from egg to adult, their reproduction rate is high, and their adult lifespan is long. Two factors that influence these characteristics are temperature and moisture. Most stored-grain insects require temperatures of more than 60° F (15° C) to develop damaging populations, and many require temperatures of 70° F (21° C) or higher. Although some grain insects are more cold hardy than others, winter temperatures common in the grain-producing areas (except for the South) are generally lethal to many stored-grain insects when the low temperatures extend throughout the grain. Furthermore, temperatures not low enough to kill insects

directly may decrease their feeding activity, thus causing many to die of starvation.

Stored-grain insects obtain water primarily from the grain itself. If the moisture content of grain is low, generally less than 10 percent, the insects must obtain water by breaking down the grain components or by using their own energy reserves. Under these conditions fewer insects survive. Although most grain is stored at moisture levels high enough to permit insect development, even small decreases in moisture content of one-half to 1 percent can significantly reduce the rate and extent of insect infestation. Properly applying these two natural control factors—grain temperature and moisture—is fundamental to developing a management program for securing and maintaining the quality of grain stored on the farm.

Basic Requirements for Grain Bins

Structures used for grain storage should:

1. Hold the grain without loss from leaks or spills.
2. Prevent rain, snow, or soil moisture from reaching the grain.
3. Protect grain from rodents, birds, poultry, objectionable odors, and theft.
4. Provide safety from fire and wind damage.
5. Permit effective treatment to prevent or control insect infestation.
6. Provide headroom over the binned grain for sampling, inspecting, and ventilating.

A suitable storage for grain includes a weather-tight, rodent-proof, metal structure that is separated from hay and feed areas and animal housing. It should be easy to clean and inspect. Adding an aeration system will allow you to cool the grain and thus limit insect development, minimize moisture migration through the grain, and facilitate distribution of fumigants.

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Figure 2—Clean the inside of the bin before new grain is stored.

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Figure 3—Spilled grain in the vicinity of the bin should be removed.

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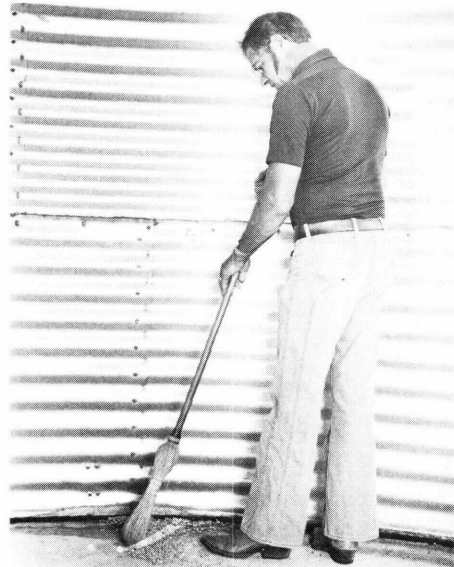
Figure 4—Spray the inside of the bin with a surface spray.

Preparing Bins for Grain Storage

Bin Cleanup

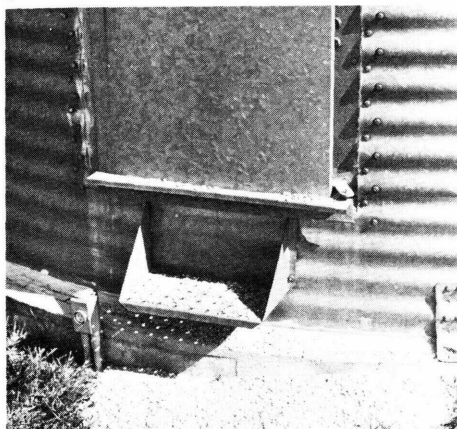
When it is binned, newly harvested grain will most likely be at optimum temperature and moisture conditions for insect development. The most important source of insects in newly stored grain is usually breeding areas in the immediate storage area. Unless steps are taken to prevent this cross-over infestation, several generations of insects could develop in summer-harvested grain before the onset of cold winter temperatures restricts development. Furthermore, small areas of extreme infestation could cause grain to heat and thus prolong damage well into the winter months.

To minimize contaminating newly harvested grain, remove all leftover grain from bins and sweep down the walls, ceilings, sills, ledges,

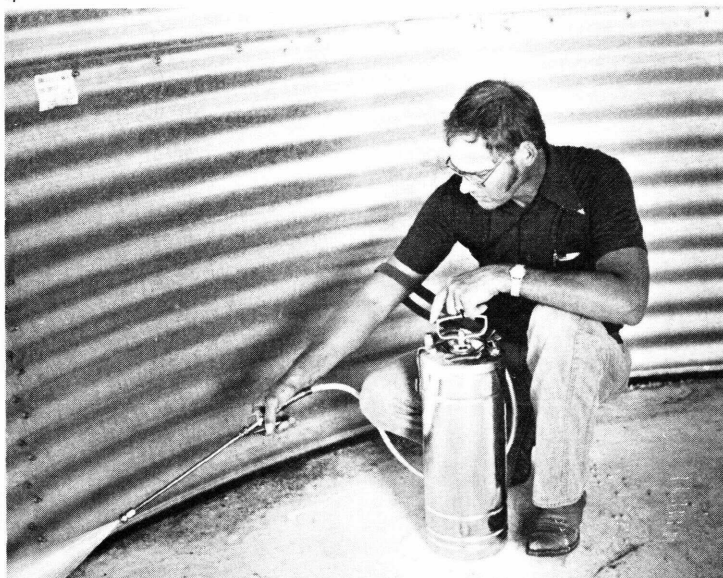


and floors (fig. 2) Destroy the sweepings. Clear trash and litter from outside the bin area and remove spilled grain from under and around the bins (fig. 3) Make all necessary repairs while the bin is empty to insure a weather-proof seal, particularly where side walls join the floor and roof.

3



4



Bin Wall Treatments

After the bin is cleaned, you should spray the inside and outside surfaces with an approved residual insecticide to kill any insects that remain in the bin or insects that may crawl across these areas to gain entrance into the grain (see fig. 4) Take special care to treat all cracks, crevices, and areas around doorways and other places where insects could enter from outside. Insecticides and rates presently approved for this use are given below:

Methoxychlor 25 percent emulsifiable concentrate: 1 quart (946 milliliters) to 2½ gallons (9.5 liters) of water. Apply 1 gallon (3.8 liters) of spray to 500 square feet (46 square meters) of surface.

Apply Protective Treatments During Binning Operation

Methoxychlor 50 percent wettable powder: Mix 1 pound (454 grams) in 2½ gallons (9.5 liters) of water. Apply 1 gallon (3.8 liters) of spray to 500 square feet (46 square meters) of surface (wetable powder suspensions should be well agitated during application).

Malathion 50 to 57 percent emulsifiable concentrate: 1 pint (473 milliliters) to 3 gallons (11.4 liters) of water. Use 1 gallon (3.8 liters) of spray for 500 square feet (46 square meters) of surface.²

Insecticides, formulas, and rates of application approved for this and other uses are subject to change. You should always purchase material that has a label stating that it may be used for the purpose. Then use only as directed on the label. Spray the bin about 4 to 6 weeks before the grain is binned.

Use Fresh Spray

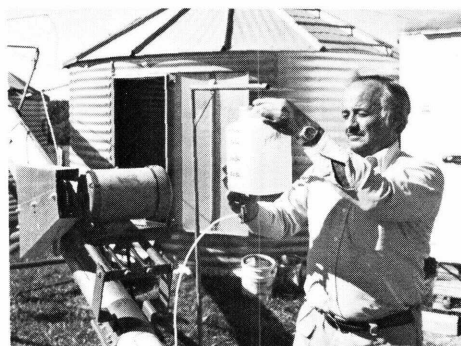
When you use a spray mixture to treat the bins, to treat the grain while binning, or as a surface dressing, mix only 1 day's supply at a time in a clean, rust-free container.

Do not use sprays that have sat overnight after being mixed with water.

One of the most important steps in limiting insects from developing in farm-stored grain is to apply insecticide to the grain as it is binned. Properly applied, this treatment will protect grain from insect damage for about one storage season. Because of the warm climate in Region 4 (see map, fig. 1), the protective treatment is often less effective there than in other regions.

Malathion is the only readily available chemical grain protectant presently approved for direct application to grain.

Apply spray as the grain is elevated into the bin or as it comes out of the combine. Mix spray and use at the rate of 1 pint (473 milliliters) of 50 to 57 percent premium-grade malathion in 2 to 5 gallons (7.6 to 19.0 liters) of water for each 1,000 bushels (35.24 cubic meters) of grain. You can apply sprays with hand sprayers, compressed-air sprayers, or sprayers operated from motor-driven pumps. You can



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Figure 5—SEA researcher measures the level of grain protectant before it is applied to the grain and loaded into the auger.

²Quinlan, J. K., White, G. D., Wilson, J. L., Davidson, L. I., and Hendricks, L. H. Effectiveness of chlorpyrifos-methyl and malathion as protectants for high moisture stored wheat. *Journal of Economic Entomology* 72:90-93. 1979.

also apply the spray mixture by letting it drip into the grain at a controlled rate as it enters the auger (fig. 5).

A simple homemade device for metering or "dripping" malathion into grain can be built by fitting two brass valves and a length of polyethylene tubing to an opening in the bottom of a plastic jug (see fig. 6). The upper shut-off cock serves as the on-off valve, while the lower needle valve regulates the amount of insecticide flowing through the plastic tubing. First

calibrate the needle valve to the desired flow rate for the amount of grain being delivered. Use the shut-off valve to start and stop flow without the need to recalibrate each time flow is turned on. Place the end of the plastic tubing about $\frac{1}{4}$ inch (6.35 millimeters) beyond the end of the auger sleeve so the insecticide drips directly into the grain picked up by the auger. Grain moving through the auger and into the bin will further distribute the insecticide.

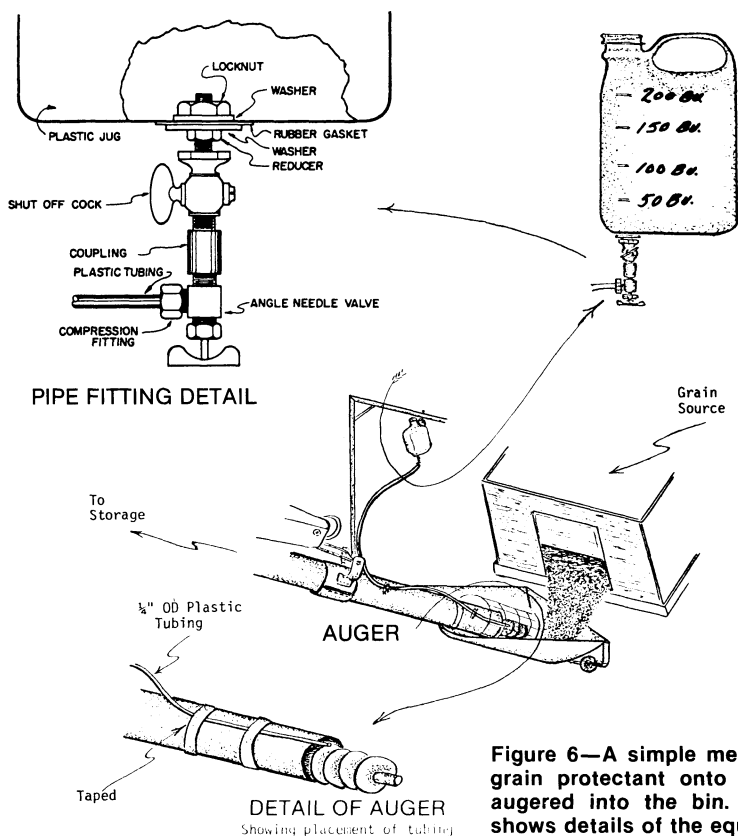


Figure 6—A simple method of metering a grain protectant onto the grain as it is augered into the bin. Insert (upper left) shows details of the equipment.

Applying Surface Dressing After Loading

After binning is completed and the grain is leveled, apply a surface dressing to help prevent insects from entering the grain or feeding on the surface. To make enough spray to treat 1,000 square feet (96 square meters) of surface area, mix $\frac{1}{2}$ pint (237 milliliters) of 50 to 57 percent premium-grade malathion emulsifiable concentrate to 1 to 2 gallons (3.8 to 7.6 liters) of water.

Some flour moths that infest grain, such as the Indianmeal moth and the almond moth, have become increasingly resistant to malathion. A commercial formulation of the biological agent *Bacillus thuringiensis*, a bacterium that controls moth larvae, has been approved for use in stored grains and soybeans. This material (see commercial label for dilution and application rate) is mixed with the surface 4-inch (10.16 centimeters) layer of grain either by adding to the last grain as it is augered into the bin or, after the grain is binned, by applying to the surface and mixing with a scoop or rake to a depth of 4 inches (10.16 centimeters). This treatment will not control weevils or other beetles that infest grain. The *B. thuringiensis* formulation is exempt from tolerance restrictions, and the treated grain can be used at any time after treatment for any use.

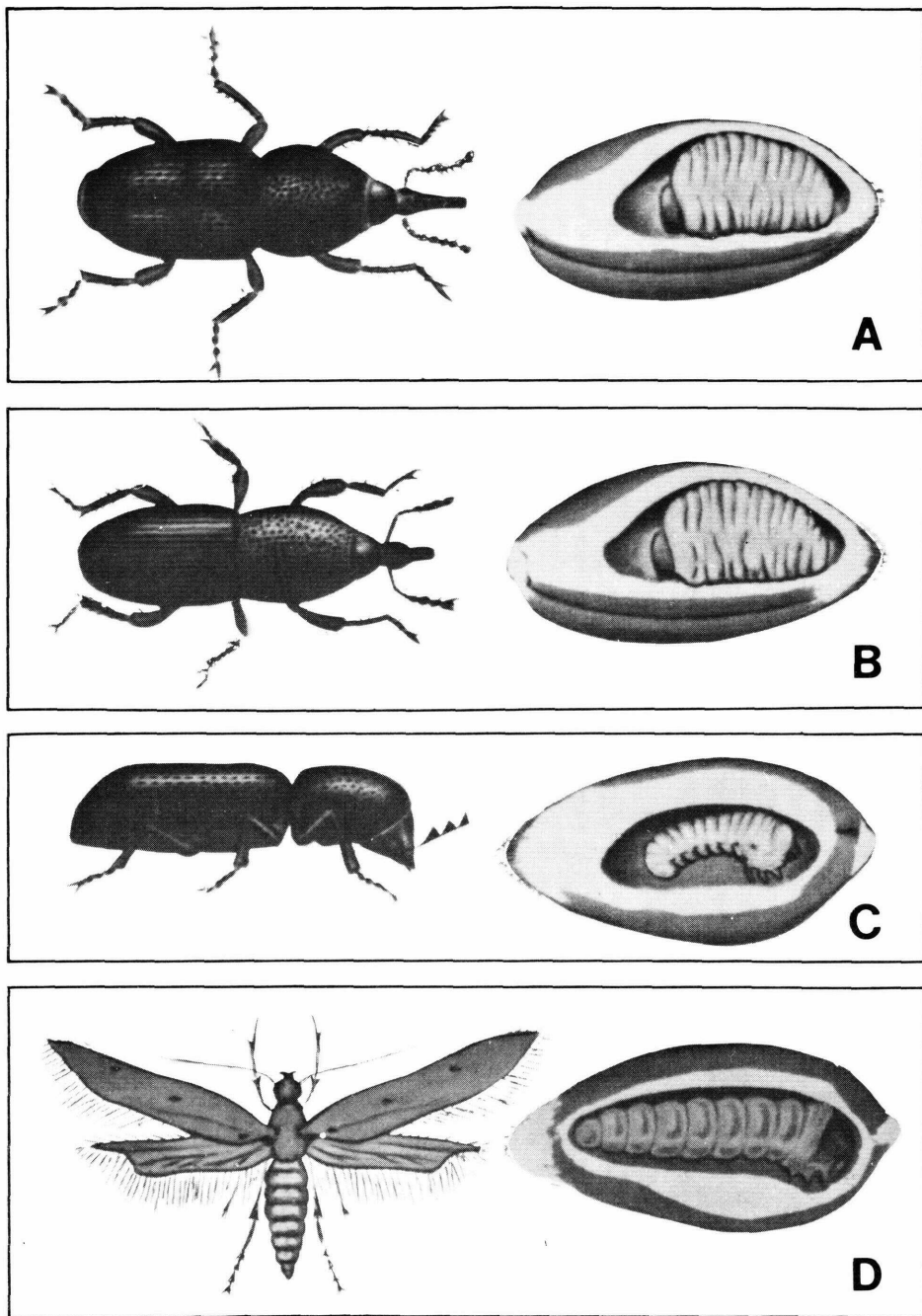
Do not step or crawl on the grain after the surface dressing has been applied. You may need to repeat surface treatment periodically,

especially if the surface is disturbed, or if temperatures are high and hazard of infestation is great.

Inspecting Grain During Storage

The probability of grain becoming insect infested or spoiled because of moisture damage and mold growth increases when it is stored and left undisturbed in the same location for several months. Therefore, you must establish and maintain a regular monthly inspection routine throughout grain storage time to determine its general conditions and to detect early insect infestation and dampness or grain heating. Inspections are particularly important during the summer and early fall months when grain temperatures are right for rapid insect development. During this part of the year, inspect the grain twice a month.

To inspect grain properly, you will need: A grain probe; a section of eave trough or strip of canvas for handling the grain from the probe; screening pans for sifting insects from the grain samples; and a means of measuring temperatures in the grain. Temperature sensor cables installed as a permanent part of the storage bin provide an excellent means of monitoring temperatures within the grain. You can also measure temperatures by fastening a thermometer to a stick and thrusting it into the grain.



PN-6734

Figure 7—Some of the most common internally developing insects in stored grain: (A) rice weevil, (B) granary weevil, (C) lesser grain borer, (D) Angoumois grain moth.

Grain temperature is a good indicator of grain condition. It serves to identify areas of the grain bulk in which conditions are favorable for insect development and also to locate areas in the grain that are heating. Stored grain contains moisture that can be shifted from one location to another primarily as a result of temperature differences that develop within the grain bulk when surface and perimeter areas of the grain cool. Moisture from warm grain is transferred to cooler parts of the grain bulk, resulting in damp areas within the grain that favor insect activity and mold development. These, in turn, cause rapid deterioration and heating of the grain.

During warm weather, infestations generally begin near the grain surface, particularly in areas directly below the point of entry where foreign material has accumulated during loading. Sample several locations in the upper portion of the grain by inserting the probe vertically to its full length and horizontally by laying the probe on the grain and pushing it an inch or two beneath the surface to collect the sample.

During cold weather, use the grain temperature as a location guide and sample areas where the temperatures are above 65° F (18° C). Sift the samples over a 10- to 12-mesh screen and examine the screenings for insects. The presence of any live stored-grain insect in the probed samples is significant, particularly if several

weeks of warm weather remain before the onset of cold temperatures.

In general, fumigate immediately if you find any adults of the rice weevil, granary weevil, maize weevil, lesser grain borer, or Angoumois grain moth (fig. 7). Emphasis is placed on these insects because most of their development occurs inside grain kernels where they are not easily detected. If you delay fumigating until these internally developing insects are plentiful, the body parts of those killed inside the kernels become a major source of insect fragment contamination when the grain is processed. Also fumigate if combinations of larvae, pupae, and adults of such externally developing insects as flour beetles, flat grain beetles, or sawtoothed grain beetles (fig. 8) exceed five or more in a 1-quart sample of grain.

To complete the inspection, look for insects on the exposed inside and outside bin surfaces, especially around the base, doors, aeration ducts, and joints or seams in the walls. Check for water leaks through the roof or walls and look for evidence of rodent or bird entry into the bin.

To help you identify the kinds of pests that damage stored and shipped grain, Agricultural Handbook No. 500, "Stored Grain Insects" is available for sale from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

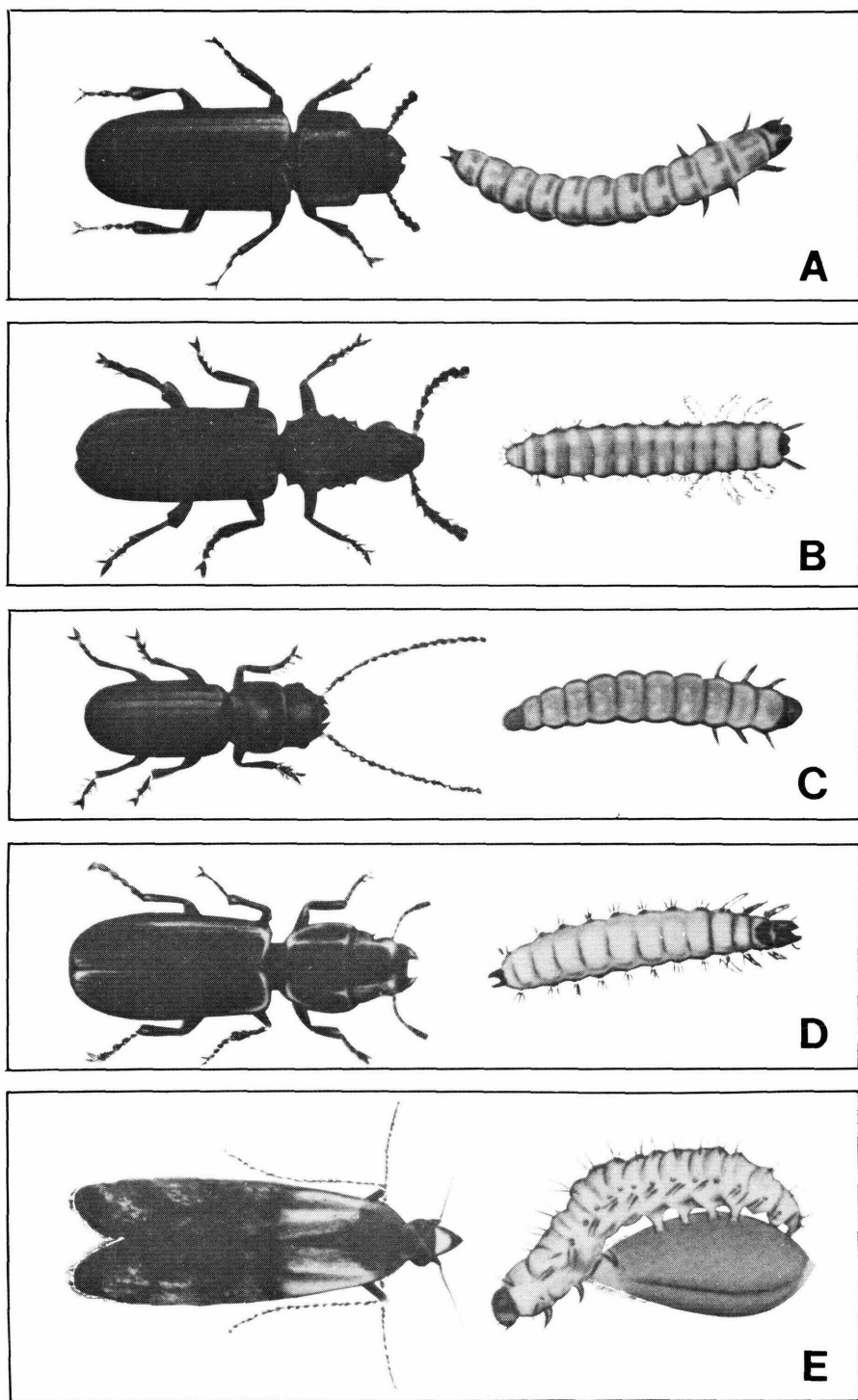


Figure 8—Some of the most common externally developing insects in stored grain: (A) red flour beetle, (B) sawtoothed grain beetle, (C) flat grain beetle, (D) cadelle, (E) Indianmeal moth. PN-6735

Fumigation

Grain fumigants are pesticides in the form of gases that penetrate throughout the grain bulk to control insects attacking the grain. Fumigants may be applied directly as gases that form when pressurized liquids are released into the atmosphere, as liquids that vaporize when exposed to the air, or as solids that produce gases on exposure to moisture in the air. Fumigants are effective only when the grain structure is sufficiently tight to maintain a gas concentration long enough to be lethal to storage pests (about 1 to 5 days). Fumigants, unlike contact insecticides such as malathion, have no residual or lingering effects after the gas has dissipated from the grain. Thus, their principal value lies in the rapid control of existing insect populations.

Because fumigant chemicals are highly toxic and hazardous to use, they are classified as restricted pesticides. Special training and certification are required before these materials can be purchased or applied. Some factors to consider when you decide to hire the services of a professional fumigant

applicator, or do the fumigating yourself, are (1) your knowledge of and experience in fumigating, (2) high cost of fumigants when purchased in small quantities, (3) special equipment required to apply fumigants, (4) safety devices such as gas masks necessary to prevent exposure to fumigants, and (5) personal risk.

Dosage and exposure time required in fumigation vary with the kind of fumigant used, commodity treated, grain temperature, and storage structure. To fumigate safely and effectively, you must follow application instructions and dosage recommendations included on the fumigant label.

The fumigation method most often used in small farm-type bins is the application of liquid fumigants in a coarse spray over the grain surface (fig. 9). This method relies on gravity to distribute the heavier-than-air vapors evolved from the liquid down through the grain. Liquid fumigants are mixtures of such chemical combinations as carbon tetrachloride, carbon disulfide, ethylene dichloride, or ethylene dibromide. Consult the fumigant label for specific dosage and safety recommendations for the mixture you select.

Before you fumigate, make sure the grain surface is level and seal the juncture between side wall and roof with masking tape. Apply the fumigant using a bucket pump or garden sprayer adapted to produce a coarse spray by replacing the

nozzle with a section of 1/4-inch (6.35 millimeters) pipe flattened on the end. Spray the fumigant over the grain surface from outside the bin. When you apply the fumigant in circular bins, avoid concentrating the spray in the center of the bin. About 50 to 60 percent of the total grain in circular bins is located in the outer 2 to 3 feet (61 to 91.5 centimeters) of grain next to the bin walls.

After you have applied the fumigant, seal the access door and fill-hole lid with masking tape or plastic sheet to prevent the fumigant vapors from venting to the outside and the wind from drawing the fumigant out of the grain.

You may also treat small bins

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Figure 9—Application of liquid fumigants through roof opening using a hand-held nozzle.



with the chemical chloropicrin. Apply it from small bottles inverted just below the grain surface. Do not treat planting seed with chloropicrin because it reduces germination.

In larger bins, distributing some fumigants in the grain can be significantly improved by using aerating equipment to push or pull the fumigant vapors through the grain in one single pass. If a return duct is added between the fan and the top of the bin, the fumigant can be recirculated several times through the grain. You can apply methyl bromide and liquid fumigants using this method. If you use liquid fumigants, you will need a power pump capable of delivering the fumigant from ground level to the top of the bin. Make all pump fittings from materials such as bronze, which resists the corrosive action of fumigants. Hoses and gaskets should be plastic or synthetic rubber.

You can apply the solid fumigant compound aluminum phosphide in the form of tablets, pellets, or packets of powder added to the grain as it is binned or transferred from one storage to another. In shallow grain storages, you can distribute aluminum phosphide through the grain by using special hollow probes that deliver the tablets or pellets into the grain. The aluminum phosphide reacts with moisture in the air and grain to evolve the fumigant gas, phosphine.

Certification Requirements to Purchase and Apply Restricted Pesticides

Laws governing the use and the users of pesticides are administered by the U.S. Environmental Protection Agency. They are designed to protect man and the environment. One such law requires that all pesticides be registered and classified either for general or restricted use. Individuals who plan to use or supervise the use of "restricted use" pesticides are required to demonstrate that they possess a practical knowledge of pest problems and pest control practices, and such knowledge must be verified by a responsible State agency through the administration of an approved applicators certification system. This practical knowledge includes ability to

- (1) Recognize common pests to be controlled and damage caused by them.
- (2) Read and understand label information—including the

common name of pesticide to be applied, pest(s) to be controlled, timing and application methods, safety precautions, preharvest or re-entry restrictions, and specific disposal procedures.

- (3) Apply pesticides in accordance with label instructions and warnings, including ability to prepare proper concentration of pesticide to be used under particular circumstances and to take into account such factors as area to be covered, speed at which application equipment will be driven, and quantity dispersed in a given operating period.
- (4) Recognize local environmental situations that must be considered during application to avoid contamination.
- (5) Recognize poisoning symptoms and know the procedures to follow in case of a pesticide accident.

Persons requiring certification should contact their local county agent, Cooperative Extension Service specialists, or State Board of Agriculture for further information about pesticides that are designated for "restricted use" and for the location and dates for training and testing under the certification program.

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Figure 10—Aeration fan and duct for using outside air to cool the grain.

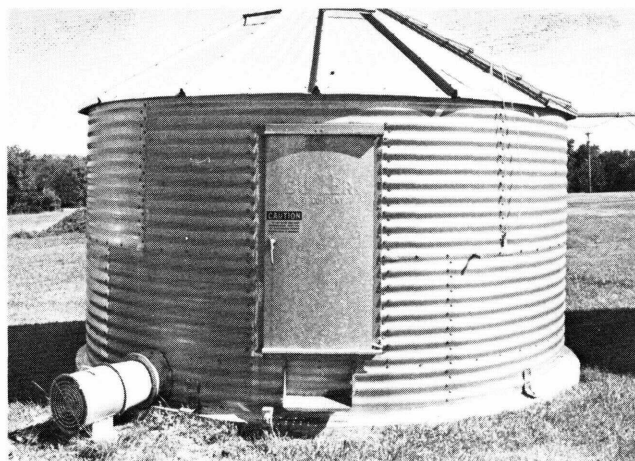
Aeration to Limit Insect Development

Insect development and reproduction are adversely affected when grain temperatures decline. Many insects die from starvation because they are unable to remain active and feed at low temperatures. Grain can be cooled by equipping grain storages with an air distribution system that forces air through the grain when atmospheric or outside air temperature is lower than the grain temperature (fig. 10). This removes heat from the grain and exhausts it from the bin. Because outside air is used in cooling grain, operating aeration equipment depends on the prevailing weather conditions. Air temperatures of 10° F (6° C) or more below the grain temperature are usually selected to cool the grain.

Generally, aeration equipment is not operated during prolonged periods of rain or fog. When cool atmospheric air is moved through grain, the incoming air and the grain through which it flows equal-

ize in temperature. This sets up a cooling front that moves in the direction of the airflow. Moisture condensation often is associated with the cooling front. Therefore, once a cooling front or zone is started through the grain, the aeration system should be operated long enough to move the zone completely through the grain mass; otherwise, a moist layer of grain may be left in the grain mass that will provide conditions for mold and insect development. Airflow rates are usually 1/10 cubic feet (2831.7 cubic centimeters) per minute per bushel or less for dry storable grain.

Aeration cooling alone may not provide complete control of insect infestations, but when used in conjunction with conventional chemical controls, it can provide considerable protection against quality losses from insect damage and contamination.



Additional Information

The following references contain much information on pests in stored grain and their control:

- (1) U.S. Department of Agriculture. 1978. *Stored grain insects*. U.S. Department of Agriculture, Agriculture Handbook No. 500. 57 p. illus. (Available for sale from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.)
- (2) Cotton, R. T. 1963. *Pests of stored grain and grain products*. Burgess Publishing Co. Minneapolis, Minn. 318 p. illus.
- (3) Monro, H. A. U. 1969. *Manual of fumigation for insect control*. F.A.O. Agricultural Studies 79. 2d ed. (rev.) 381 p. illus.
- (4) U.S. Department of Agriculture. 1979. *Guidelines for the control of insect and mite pests of foods, fibers, feeds, ornamentals, livestock, forests, and forest products*. U.S. Department of Agriculture, Agricultural Handbook 554. 822 p. (Available for sale from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.)

For additional references and information on specific problems related to grain storage pest control and for methods recommended for your region or state, consult your local county agent, Cooperative Extension Service specialist, or your State Board of Agriculture.